# FUTURE COMMUNICATION STUDY - ACTION PLAN 17
# FINAL CONCLUSIONS AND RECOMMENDATIONS REPORT

*Nikos Fistas, EUROCONTROL; Brent Phillips, ATO FAA;*
*James Budinger, NASA Glenn Research Center*

## Abstract

This paper provides a summary of the final report out of the joint activities of FAA and EUROCONTROL to investigate the future aeronautical communications under the Action Plan 17 of the FAA/EUROCONTROL MoC. The paper concludes with the resulting recommendations and proposed actions.

## Introduction

The need for adequate future communication capability was discussed at the ICAO Eleventh Air Navigation Conference (AN-Conf/11). In its conclusions, AN-Conf/11 agreed that the aeronautical mobile communication infrastructure had to evolve in order to accommodate new functions and to provide the adequate capacity and quality of services required to support evolving air traffic management (ATM) requirements within the framework of the global ATM operational concept.

In order to achieve these objectives, AN-Conf/11 developed three relevant recommendations:

1. Recommendation 7/3 - Evolutionary approach for global interoperability of air-ground communications. This recommendation promotes the continuing use of already implemented systems (supporting voice as well as data), the optimisation of the available spectrum utilisation, and the consideration of transition aspects.

2. Recommendation 7/4 - Investigation of future technology alternatives for a/g communications. This recommendation addresses the need for investigations to identify the technology candidates to support the future aeronautical communications, and

3. Recommendation 7/5 - Standardization of aeronautical communication systems. Finally this recommendation emphasises the need for standardisation activities for technically proven technologies which provide proven operational benefits.

At AN-Conf/11 there was a strong request particularly from the airlines (represented by IATA) for international co-operation in order to achieve the stated objectives and goals in a harmonised and globally interoperable manner, particularly for air/ground communications.

In line with the AN-Conf/11 recommendations, EUROCONTROL and the U.S. Federal Aviation Administration (FAA) decided to establish a dedicated working arrangement (Action Plan 17 of the EUROCONTROL-FAA Memorandum of Cooperation) to progress this work in a consistent manner in Europe and the U.S.. AP17 has been very closely coordinated with ICAO ACP as a means to achieve world wide consensus and global harmonisation.

## Future Communications Study – Action Plan 17

The AP17 is a joint activity between FAA/NASA and EUROCONTROL. Under the U.S. AP17 activities, NASA Glenn Research Center (GRC) was asked by the FAA to lead the U.S. technology investigation. In Europe, France, Germany, Spain, Sweden and the U.K. have also been actively supporting and contributing in the European investigations. The work undertaken under AP17 has also been supported by MITRE and ITT Corporation in the U.S. and by QinetiQ in Europe.

The AP17 partners agreed that the activities need to allow a realistic transition for service providers and airspace users, to support air traffic services (ATS) and airline operational control (AOC) data communications for safety and regularity of flight (including air/air communications), and to address spectrum depletion in the high density regions of both Europe and the U.S.

It was agreed that in the longer term, a paradigm shift will occur in the operating concept and the prime mode of communication exchanges will be based in data exchanges rather than voice communications as it is today. Based on the outcome of the initial AP17 activities, the partners agreed to focus the investigations on data communications and consider that the existing VHF systems (analogue voice and data link) will be used as required to cover the short and medium term needs.

The AP17 progress has been closely monitored at the highest management levels of FAA and EUROCONTROL, with regular feedback and steering. In addition the progress of the work has also been regularly presented in the ACP/WGC meetings. The feedback and comments were instrumental in the continuation, focusing and steering the activities.

The AP17 activities have been closely coordinated with the relevant stakeholders in the U.S. and Europe. In the U.S. the work is being closely coordinated with the multi-agency Joint Planning and Development Office (JPDO) Next Generation Air Transportation System (NextGen) initiative. In Europe the work is being closely coordinated with the EUROCONTROL/European Commission Single European Sky ATM Research (SESAR) Programme.

In the U.S., NextGen will support the projected future increased demands in air traffic. This system of systems will support a projected vision of the U.S. National Air Space System for the 2025 time frame. This will require a transition plan which will include significant research, development and implementation of multiple technologies. The projected Concept of Operation in 2025, which includes trajectory based and performance-based operations, net-centric services and shared weather information, calls for increased data communications which can provide timely, accurate, secure and comprehensive information.

In Europe, SESAR is the European ATM modernisation programme, combining technological, economic and regulatory aspects in order to synchronise the plans and actions of the different stakeholders. SESAR will lead the definition, development and implementation of the required improvements both in the airborne and ground systems in Europe. Currently the Definition Phase is being completed, which will deliver a European ATM Master Plan covering development activities up to the 2020 timeframe. From 2008 up to 2015 will be the Development Phase of the required new improvements. These new improvements will be implemented in the Implementation Phase from 2013 onwards (with 2020 being the target to implement the required improvements). In Europe a specific entity, the SESAR Joint Undertaking (SJU), is being set up to manage the activities following the definition phase.

AP17 has been a highly collaborative study with careful work planning leading to the effective use of resources to avoid duplication, and successful information sharing. Among the major achievements of AP17, are: 1) the establishment of future aeronautical communications concepts of operation and requirements (COCR); 2) the identification of enabling technologies; and 3) the development of a roadmap for the future communications infrastructure (FCI) that covers the transitions from now through to 2030. The AP17 outcome is supporting the communication objectives of SESAR and NextGen, which are pacing the transition to the future ATM system. The very close and efficient cooperation between U.S. and European experts has enabled convergence and agreement on joint recommendations as directed by AN-Conf/11.

The AP17 work considered several Technical Tasks for progress. In addition, non-technical actions, referred to as Business Tasks, were also considered. The Business Tasks are essential to create “dynamics” and maintain commitment. Overall, there were 6 technical tasks and 3 business tasks. The content of the various tasks and their achievements are summarised in the following sections.

## *Technical tasks*

### *Task 1: Improvements to Current Systems - Frequency Management*

Particularly in Europe, the VHF band is already congested today. It is very difficult for example to find new frequencies for new sectors or services in core Europe. This situation is becoming worse and congestion will also appear in peripheral states as well. In Europe the 8.33 KHz programme has been introduced and is currently being expanded to provide much needed relief. However, even with the introduction and use of the 8.33 KHz channelisation, the benefits are expected to be short term as in the longer term the congestion levels will increase again in line with the expected traffic increase.

While the VHF band is also heavily utilised in the U.S., the congestion is not as critical as in Europe. Whereas the long term availability of frequencies is also of concern, there are options such as the use of 8.33 KHz spacing if required.

In the context of the AP17, it was agreed that exchanging experience and expertise on frequency management aspects could help to extend the continued use of the current systems (primarily voice) and at the same time, better prepare for the future communication system. It is generally agreed that prolonging the life time of the VHF band (i.e. to be capable to satisfy new requirements in this band for traditional ATS and AOC air-ground voice communications services) is absolutely vital to aviation, especially in the short to medium term, in which there are no other options.

A good understanding of the frequency management procedures in the two regions has been established and the experience gained will be used as appropriately. A key difference is that in U.S. there is centralised management with one body (the FAA) supervising the whole process, covering the operational requirement justification up to the implementation in the radio sites, whereas in Europe each state is responsible for managing its own frequency assignments and the cross-border coordination requires consensus.

### *Task 2: Identify the Mobile Communication operational concept*

The outcome of the intense activities under this task is contained in the Communications Operating Concept and Requirements (COCR) document. The development of the COCR has been an intense collaborative effort of U.S. and European experts and it captures the requirements that future communications systems will need to meet for emerging ATS and AOC concepts and strategies to support the technology assessment process. The COCR covers two main phases: Phase 1 (from now to 2020) and Phase 2 (beyond 2020). Phase 1 is based on greater use of air/ground data communications, but remains largely human centric. Phase 2 is based on more extensive use of Phase 1 services and takes into account concepts emerging from the SESAR initiative in Europe and the NextGen initiative in the U.S. Key changes in Phase 2 include the use of 4D trajectory management, greater information exchange between the aircraft and the ground systems to support automated conflict resolution and the introduction of autonomous operations in some parts of the airspace.

From the operational concepts, information flows have been identified in representative test volumes of airspace i.e., ‘positions/sectors’ in airport, terminal maneuvering area (TMA), en-route, and oceanic. This includes all ATS and AOC air/ground and air/air voice and data communication including Automatic Dependent Surveillance - Broadcast (ADS-B). New types of aircraft such as micro-jets and Unmanned Aircraft Systems (UAS) have been included on the basis that they occupy the same airspace and have the same ATS communication requirements as other types of aircraft. However, while ATS communications between UAS pilots and air traffic controllers has been included within the scope of the COCR, the command and control link for UAS has not. Also, security applications such as down linking of onboard aircraft video were also considered to be outside the scope of the COCR.

From the operational concepts the communication requirements have been derived taking into account safety and security analyses. It should be noted that the requirements are technology independent. The determined requirements parameters include:

- Communications capacity needed in the various airspace types, and
- Availability, continuity, integrity and latency requirements.

The per service volume capacity requirements for air/ground and air/air communications were determined using a representative queuing model to support the identified services. In the timeframe of Phase 2, the capacity requirements for ATS and AOC air-ground communications in high density airport and en route environments were approximately 200 kbps (per service volume). For the TMA and oceanic/remote/polar environments, capacity of approximately 40 kbps (per service volume) was determined to be required.

The COCR also identified stringent requirements in Phase 2 for availability, continuity, integrity and latency both on an end-to-end basis as well as for the radio system. These requirements are necessary to support the anticipated data link services in this timeframe.

The COCR is a comprehensive document which used a top down requirements driven approach to develop future communications requirements. It has been used as the basis for the technology assessments as reported below. It was presented to various stakeholders and ACP and it was accepted as the basis for the requirements determination. In addition, the COCR was provided as input material to SESAR in Europe and NextGen in the U.S. To facilitate the technology evaluations and to ensure that a common set of performance requirements are applied equitably, a set of evaluation scenarios has also been developed based on an extension of the service volumes in COCR.

These are contained in the Evaluation Scenarios document which provides a library of evaluation scenarios which can be utilised by each technology in the most appropriate manner.

### *Task 3: Investigate new technologies for mobile communication*

Task 3 was conducted to evaluate applicable technologies to satisfy the needs of the communication concepts for the Future Communication Infrastructure (FCI) defined in the COCR. The task was performed in several phases through coordinated and cooperative efforts of two teams: a European team and an FAA/NASA/ITT team, from 2004 through 2007. The evaluation included identification of a set of over 50 candidate communications technologies; definition of an operational concept for application of the technologies to the FCI; and simulation/evaluation of technology performance and applicability.

The initial set of study activities included a joint effort to survey applicable technologies, define a concept for application of the technologies to the future aeronautical environment, and perform a technology pre-screening. Coordinated follow-on activities consisted of down selection of the most promising technologies through in-depth technology performance studies and evaluation of these technologies against well-defined criteria. Throughout follow-on activities the two study teams conducted detailed review and discussions to share results, solicit comments, and harmonize technology recommendations. A summary of the Technology Evaluation methodology is provided in Figure 1.

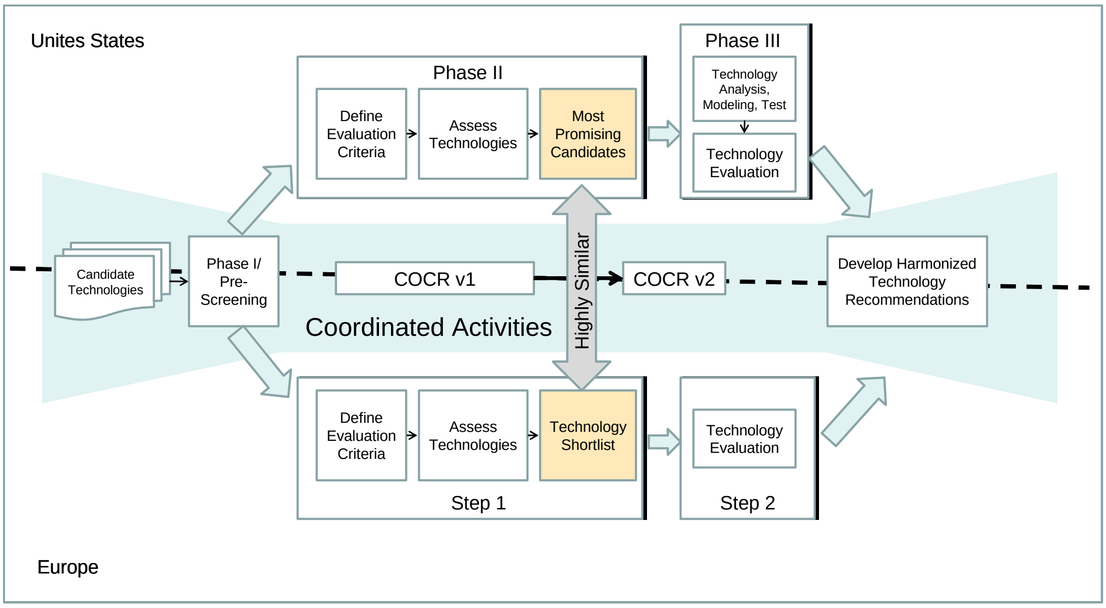


**Figure 1: Technology Evaluation Methodology**

An important harmonization step during the Step 1/Phase II investigations was the review of work to identify the most promising technologies for further investigation. After each team individually examined requirements and applied a subset of the evaluation criteria in a technology down select process, the teams found significant overlap in the resulting sets of most promising technologies (also called the technology shortlist). These results are shown in Figure 2. The technologies assessed are the following: TIA-902 (P34), L-band Data Link (LDL), Wideband Code Division Multiple Access (WCDMA), INMARSAT SwiftBroadband (SSB), Custom Satellite and 802.16e. The Broadband Aeronautical Multi-carrier Communications system (B-AMC) and the All-purpose Multi-channel Aeronautical Communication System (AMACS) have also been investigated primarily in the frame of the European activities. LDL is an evolution of the VDL3 system, B-AMC is an evolution of the Broadband-VHF (B-VHF) proposal, and AMACS is a combination of the VDL4 system and the ETDMA (Enhanced TDMA) proposal. The term, “Custom Satellite,” refers to both new commercial satellite offerings specifically designed to address FCI requirements as well as government/private initiatives for satellite designs specific to aviation communications.

The results and recommendations of the technology investigations can be organized by proposed operating frequency bands. These are described in the following paragraphs.

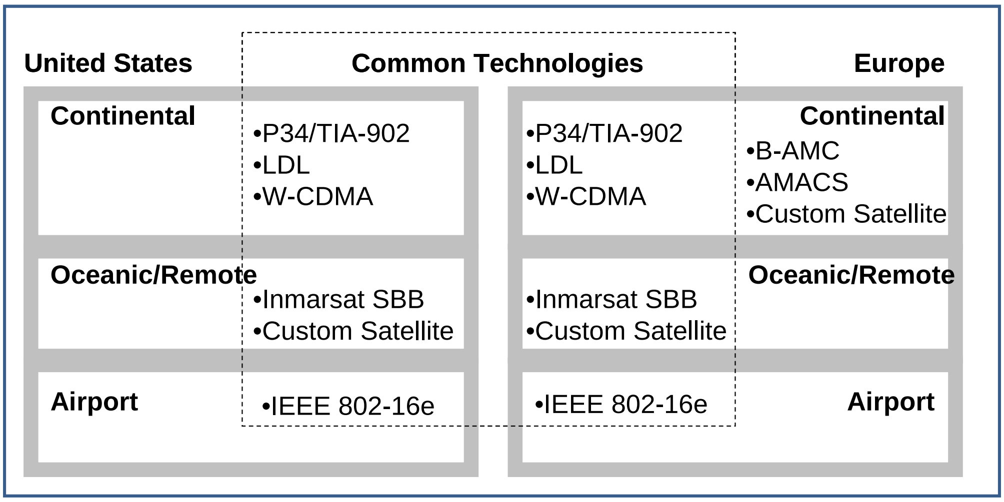


**Figure 2: Evaluated Technologies: Final Shortlist**

### C-band

Many major accomplishments were realized during the technology investigation effort. One was the joint identification and recommendation of an IEEE 802.16e-based system as the solution for the provision of dedicated aeronautical communication services on the airport surface utilizing proposed aeronautical C-band allocations. This technology, designed for short-range, high data rate communications in C-band, is well matched to the airport surface environment in terms of capability and performance. Additionally, simulation of this technology in this aeronautical channel environment yielded very favourable results. The proposal for the C-band data link builds upon currently ongoing activities including testing of the standard 802.16.

The C-band recommendations are to:

- Identify the portions of the IEEE 802.16e standard best suited for airport surface wireless mobile communications and propose an aviation specific standard to appropriate standardisation bodies;
- Evaluate and validate the performance of the aviation specific standard to support wireless mobile communications networks operating in the relevant airport surface environments through trials and test bed development; and
- Propose a channelisation methodology for allocation of safety and regularity of flight services in the band to accommodate a range of airport classes, configurations and operational requirements.

### AMS(R)S Band

A second accomplishment was the harmonized definition of the role of satellite services in the FCI, particularly for support of operations in the oceanic and remote airspace domains. The study teams recognized the unique capabilities of satellite communication systems to provide adequate coverage over large and/or remote geographic areas. It is important to note, however, that the defined operational concept for the FCI (2020 and beyond) is beyond the service horizon of current satellite offerings for aeronautical mobile satellite (route) services (AMS(R)S). Some existing service offerings such as INMARSAT SBB have been identified as potentially suitable for meeting the service requirements for oceanic/remote airspace in specific geographic locations. The potential of next generation satellite systems, particularly those systems customized to meet the needs of aviation (including custom commercial solutions such as Iridium-NEXT and custom government/private solutions such as the European Space Agency (ESA) initiative (ATM SATCOM) was also recognized. In the European activities, the future satellite systems are also being investigated as a complement of the terrestrial infrastructure to jointly meet the future stringent requirements in the high density continental airspace.

An issue that was raised in the investigations was the adverse impact of the proliferation of technologies in the airborne equipment which result in multiple options for equipage. In this context, the availability of a globally applicable standard covering the requirements of the COCR may facilitate to address some of the institutional issues associated with satellites. If such a standard would be adopted by the interested parties, it would support interoperability while minimising airborne equipment requirements.

The satellite band recommendations are to:

- Continue monitoring the satellite system developments and assessment of specific

technical solutions to be offered in the timeframe defined in the COCR as these next generation satellite systems become better defined;
- Update existing AMS(R)S SARPs performance requirements to meet future requirements; and
- In order to support the new AMS(R)S SARPs, consider the development of a globally applicable air interface standard for satellite communication systems supporting safety related communications.

An important feature of the satellites is the support for non line-of-sight communications. Today, this functionality is also provided by HF systems supporting both voice and low rate data communications especially in the oceanic environment. These already deployed systems will continue to be employed in the FCI. Any new HF system could also be considered in the frame of the FCI.

**VHF-band**

The investigation of technologies to provide future data communication capabilities in continental airspace domain (en route/terminal/surface) focused on technology concepts for deployment in the aeronautical VHF and L-bands. While none of the existing data link technologies meets the long term aeronautical requirements, some proposed technologies in the VHF-band were identified for consideration for the future radio system. However, in the end in large part due to current spectrum congestion considerations, the technology investigations focused in the L-band. In the longer term, the applicability of the VHF band may also be reconsidered.

The VHF band recommendation is to:

- In the longer term, reconsider the potential use of the VHF-band for new technologies when sufficient spectrum becomes available to support all or part of the requirements.

**L-band**

For en route and TMA airspace, the L-band was identified as the best candidate band for meeting the future aeronautical communications, primarily due to potential spectrum availability and propagation characteristics. As a result of this finding, another accomplishment of the technology evaluation was the recommendation to seek co-primary allocations for AM(R)S in the aeronautical L-band at the upcoming World Radiocommunications Conference (WRC-07).

In light of the importance of the L-band, significant effort was devoted to define and model the L-band channel and interference environment, including development of an initial channel model. Further work is required to refine and validate the channel model. Analyses of the legacy aeronautical L-band systems (including DME, UAT and Mode S), interference scenarios, and development of a laboratory test methodology were also performed. This work was used to conduct initial investigations of technology performance in the L-band. It is noted that the assumptions used for the interference investigations are critical for determining compatibility. As a result, primarily of the channel and interference investigations and the performance assessment of the technologies, it was concluded that a thorough evaluation of the compatibility in the band is required.

As a result it is recommended to:

- Refine and agree on the interference environment and assumptions for the L-band compatibility investigations.

As a result of the initial performance analysis of the short-list of technologies in the anticipated channel and interference environment and against defined criteria, it was found that none of the considered technologies could be fully recommended. However, the assessment of these technologies led to the identification of suitable technology features that could be used as a basis for the development of an acceptable L-band data link solution. For example, some technology features specifically address operation in a fast fading environment or have low duty cycle transmissions, which is beneficial in mitigating interference. Considering these features and the most promising candidates, two options for the L-band Digital Aeronautical Communication System (L-DACS) were identified. These options warrant further consideration before final selection of a data link technology. The first option represents the state of the art in the commercial developments employing modern modulation techniques and may lead to utilisation/adaptation of commercial products and standards. The second capitalises on experience from aviation specific systems and standards such as the VDL3, VDL4 and UAT.

The first option for L-DACS includes a frequency division duplex (FDD) configuration utilizing OFDM modulation techniques, reservation based access control and advanced network protocols. This solution is a derivative of the B-AMC and TIA-902 (P34) technologies. The second L-DACS option includes a time division duplex (TDD) configuration utilizing a binary modulation derivative of the implemented UAT system (CPFSK family) and of existing commercial (e.g. GSM) systems and custom protocols for lower layers providing high quality-of-service management capability. This solution is a derivative of the LDL and AMACS technologies. Table 1 depicts the two options.

| | Access scheme | Modulation type | Origins |
|---|---|---|---|
| **L-DACS 1** | FDD | OFDM | B-AMC, TIA 902 (P34) |
| **L-DACS 2** | TDD | CPFSK/GMSK type | LDL, AMACS |

**Table 1: L-DACS (the L-band data link) options key characteristics**

In addition to air/ground communications capability, some of the assessed technologies could support air/air (point to point and/or broadcast) communications services. B-AMC, AMACS and TIA-902 (P34) have provisions to support such services. However this capability needs further investigation as a possible component of L-DACS.

Follow-on activities to further characterize the proposed L-DACS solutions, validate performance, and lead to a single technology recommendation for this band are required.

To complete the selection of the L-DACS solution, it is recommended to:

- Complete the investigation of compatibility of prototyped L-DACS components with existing systems in the L-band particularly with regard to the onboard co-site interference and agree on the overall design characteristics;
- Evaluate and validate the performance of the proposed solution in the relevant environments through trials and test bed development; and
- Considering the design trade-offs, propose the appropriate L-DACS solution for input to a global aeronautical standardisation activity.

**General aspects**

Considering also the developments in ACP/WGI, it is assumed that the FCI will employ an ATN/IP infrastructure. When finalising the selection of the new components of the FCI further testing and validation should be carried out within an end-to-end IP environment to ensure that the required Quality of Service (QoS) and performance can be achieved.

During the AP17 activities, the use of Commercial-Off-The-Shelf (COTS) products to benefit from commercial developments and synergies was recognized as a preferred solution to support the future aviation communication requirements. Results of the investigations however showed that no COTS technologies are currently available which meet all the requirements. Nevertheless, reuse of COTS components/elements is encouraged throughout future system identification and development efforts.

### *Task 4: Identify the communication roadmap*

In line with the phased communications operating concept described by the COCR, the Communications Roadmap was developed to describe the evolution of the communication infrastructure. The roadmap recognizes the needs of the aviation users as well as air navigation service providers, ensures the judicious use and protection of spectrum allocated for aeronautical purposes, and focuses on the introduction of potential new technologies for specific airspace and services.

Figure 3 depicts an overview of the jointly agreed to approach for the implementation and evolution of aeronautical mobile communications to support the emerging and anticipated needs of air traffic management in both Europe and the U.S. This is expected to become the basis for globally harmonised communications.

Near term, air traffic control operations will continue to use the VHF spectrum for voice communications throughout the U.S. and European regions. 8.33 kHz channel spacing has been implemented for the VHF band in Europe, and will continue to expand vertically into more airspace as needed to satisfy demand for voice channels.

Initial data link using VDL2 in European airspace is being implemented to support ATC data services, such as CPDLC. Mandatory carriage of equipment to support these services is expected for certain airspaces in Europe, from 2009 (forward fit) onwards.

The U.S. is optimizing its use of VHF spectrum to ensure sufficient capacity for data operations, and to provide needed voice channels. In the same time frame, the FAA DATACOM program will begin to develop and implement data applications in the U.S. domestic airspace, using available communications technologies (i.e.VDL2) and aircraft equipment. 8.33 kHz voice channel spacing will be employed if necessary to increase

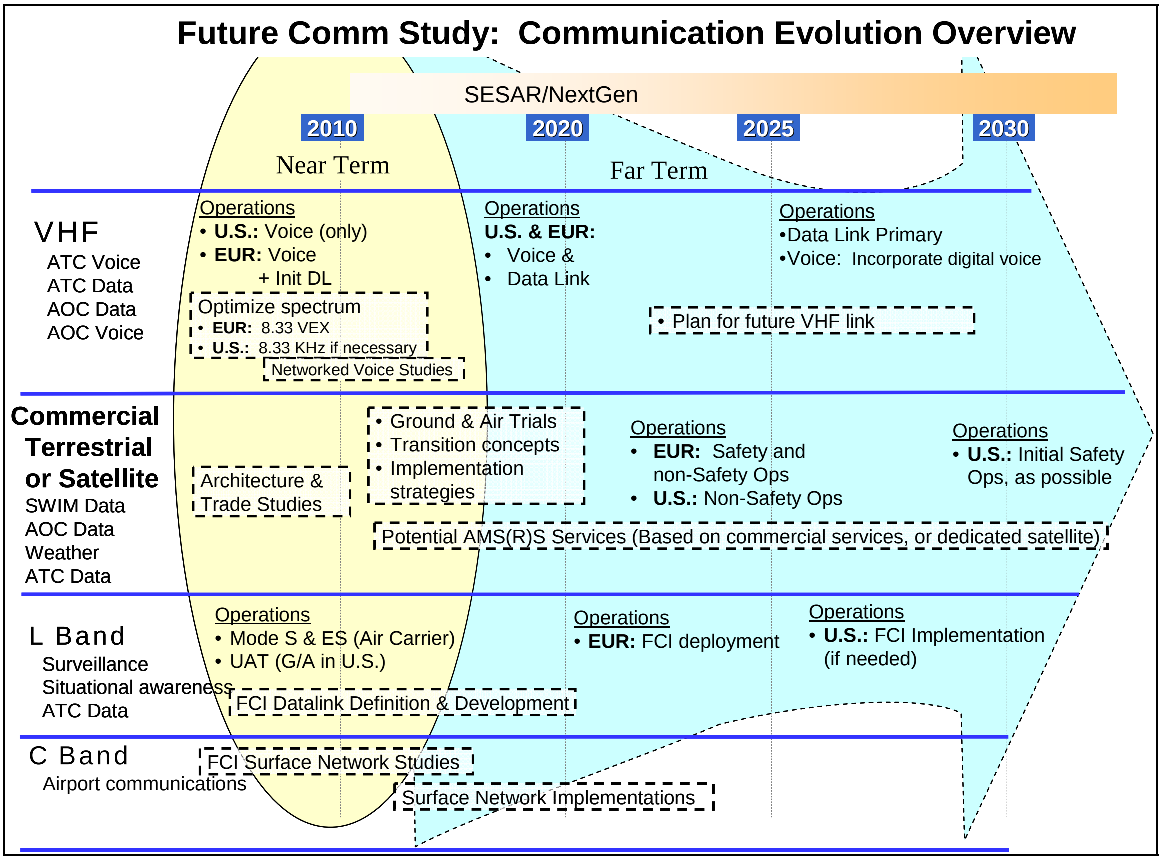


**Figure 3 – Aeronautical Mobile Communications Evolution Overview**

the amount of spectrum available for data link services.

Surveillance applications in both the U.S. and Europe will continue to use L-band communications at 1030/1090 MHz for SSR/ATCRBS. In addition, both regions will support ADS-B using 1090 ES. The U.S. will also be implementing UAT to support ADS-B services. In Europe, VDL4 is also being implemented on a regional basis.

To prepare for the far term, FAA and Eurocontrol will continue to study the potential for emerging commercial terrestrial-based and satellite communications technologies for non-safety communications. In addition, the potential use of dedicated satellite systems to support safety communications is being considered in Europe. Opportunities to validate the concepts of use, or implementation strategies for these technologies would be performed through ground and airborne trials and demonstrations.

The FAA and Eurocontrol will also engage in joint activities to complete selection of the terrestrial based L-band digital link (L-DACS), to provide additional aeronautical mobile communications capacity. Regional limitations of the VHF band in Europe may drive implementation of the jointly developed terrestrial L-band digital link technology in the 2020 time frame. As circumstances dictate, the FAA will also consider the L-band digital link technology for use in the U.S. Considering the long time cycles in aviation to develop, validate, standardise and deploy a new system, it is critical that these activities are carried out expeditiously.

Wireless airport communications links using the C-band spectrum allocations at 5 GHz are recommended for deployment as surface area networks. Applications that may be considered for use in this frequency band include surveillance and weather sensor information transfer; monitor and control of aerodrome navigation and landing aids; support for information transfer between automation systems; and Electronic Flight Bag and other mobile applications supporting aircraft and surface vehicles.

Once digital data communications is established, and the operational paradigm changes to be based on digital information exchange as the prime means for safe and efficient ATC operations, it is expected that the need for data communications will grow and the nature of voice communications will change. In the long term, digital voice may also be used.

### *Task 5: Investigate feasibility of airborne communication flexible architecture*

In order to ease migration towards new systems, the importance of the flexibility of the airborne architecture has already been identified. This task set out to capitalise on the on-going developments in the telecommunication industry and investigate the feasibility of a flexible airborne architecture and the appropriate enablers including multi-mode/software radio and “agile” antennas. The need for new components for the future communication infrastructure as well as the continuing use of existing technologies will result in changes to ground infrastructure as well as the avionics.

In particular the integration of new and old components onboard the aircraft is a critical area that needs careful consideration to address a multitude of issues such as interference, certification, physical space limitations, and human factors.

In this context EUROCONTROL commissioned an “Aircraft Architecture Study” to investigate the future communication architectural requirements and enablers for a flexible airborne architecture. The study investigated possible approaches to considering not only the communication elements of future aircraft architectures but also how an overall approach could be adopted to more easily introduce change. The study concluded that the future avionics architecture could see a realisation of evolving technologies to provide the functionality required of a flexible and expandable system. This will include a high degree of integration of cockpit avionics operating on a modular and extendable computing capability to provide flexibility, redundancy and support for improvement.

The EUROCONTROL study provided rationale to reduce the number of aircraft antennas and to provide more capability for each aperture in the aircraft’s surface. This reduced antenna set will provide input to a number of software-defined radios (SDRs). These SDRs will provide the flexibility to adapt to changes in frequency, modulation and encoding in order to provide access to the developing communication capability. SDRs will provide their data as information services, via a robust and extendable network infrastructure, to support cockpit avionics, operational avionics and cabin information services. There could be a similar degree of integration for operational and cabin services which will be partitioned to reduce costs in certification. The net result will be adaptable and expandable avionics architecture able to evolve with the rapidly expanding communications capability.

In the U.S., NASA GRC initiated the concept and development of multi-function, multi-mode digital avionics (MMDA). GRC’s objective was to demonstrate an MMDA prototype that illustrates the potential for lower total system cost and faster certification and re-certification processes, in comparison with conventional independent avionics equipment. Applied to the FCI, the MMDA concept should be considered for both the on-board and ground-based systems that implement multiple modes of communications, potentially in and across the various frequency bands allocated for safety critical communications.

Multiple preliminary assessment and analysis studies were conducted by industry partners. GRC also initiated and chaired the Avionics Special Interest Group (SIG) under the Software Defined Radio Forum.

Based on EUROCONTOL and U.S. findings, the following recommendations emerge:

- Support activities and engage with aircraft manufacturers, aircraft operators and industry standard groups to ensure that a flexible airborne architecture evolves to ease the cost and time of certification and readily accommodate new applications and technologies; and
- Encourage industry investigations into flexible airborne architectures, software defined avionics, and multi-function, multi-mode antennas.

### *Task 6: Identify the Spectrum bands for new system*

Spectrum availability and interoperability with existing systems are primary considerations in the selection of new technologies of the FCI.

The activities in this task consisted in providing appropriate support to the ICAO group dealing with spectrum matters (ACP WGF) and relevant ITU groups involved in the WRC-07 Conference preparations.

A key outcome of this activity was the identification of the required spectrum (60 MHz for the L-band and 60-100MHz for the C-band) to support the requirements of the FCI taking into account the input out of Task 3 of AP17. The results of this task were used as inputs both in the U.S. and European sides to define their positions for WRC-07.

Currently, there are 3 options that are being considered for AM(R)S allocations at WRC-07. Taking into account the characteristics (propagation) and implications (power) for any system that may be eventually allowed to operate in the above bands and taking into account the emerging capacity requirements for the different airspace domains the optimised usage of the considered bands could be as follows:

- VHF band: upper VOR band ([112 or 116]-118 MHz)
  This band (an extension of the current 118-137 MHz) could be used to either support existing services (e.g. transition) or to allow for the introduction of new systems in all continental airspace.
- L-band: lower part of the DME band (960-[1024 or 1164] MHz)
  This band could be used to support services in all continental airspace.
- C-band: [5000 to 5010] MHz, and/or [5010 to 5030] MHz, and/or 5091 to 5150 MHz
  This band could be used to support surface applications at airport.

In order to preserve flexibility, generic AM(R)S allocations should be secured in all considered bands.

Recognizing the dependence of FCI on having sufficient and suitable spectrum available, the spectrum recommendations are to:

- Continue to provide rationale to spectrum regulators on the need for additional AM(R)S spectrum to facilitate advances in aeronautical communication capabilities;
- Provide support for compatibility studies between the FCI and other incumbent systems in any newly-allocated AM(R)S bands. This will include studies within ICAO regarding FCI compatibility with other aeronautical systems, and studies within the ITU regarding FCI compatibility with non-aeronautical systems; and
- Continue to support the need for priority to AMS(R)S in the satellite L-band.

## *Business Tasks*

### *Business Task 1: Create Multi National Framework*

The activities in this task were primarily focused in providing regular updates to ICAO (ACP, WGW, and WGC) and seeking feedback and comments for the continuation of the work.

In particular ACP/WGC has been continuously briefed on the progress of the work in the various tasks. The feedback and comments of the WGC participants were instrumental in the progress and the direction of the activities in all tasks and in particular to the tasks dealing with the identification of the requirements and the technology investigations.

### *Business Task 2: Create Industry interest*

Industry interest is recognized as an important factor in contributing to the success of achieving the desired objectives of the AP17. As a result, a number of approaches were employed through out the study to help increase the awareness and involvement of potential stakeholders. As a means of gaining international consensus and converging towards a globally harmonized solution, the FAA/Eurocontrol team presented updated study results to the ICAO ACP on a frequent basis as covered in Business task 1. In addition, EUROCONTROL presented results to the Communication Team (COMT) and the Air-Ground Communications Focus Group to provide updates and gather feedback from European stakeholders including industry, and ANSPs. The FAA provided a mid-course presentation to the RTCA Air Traffic Management Advisory Committee as a mean of gathering further support and direction from the U.S. Airline Industry. The team also provided presentations at a number of open forums/conferences including the ATN 2000+ and the Integrated Communications, Navigation and Surveillance Conference (ICNS) as a means for further dissemination of the information and obtaining feedback. Finally, the study was designed to allow system specific constituents to participate in the technology design and characterization process. These industry relationships will continue to evolve through the SESAR and NextGen programs.

### *Business Task 3: Business Model*

An important element in realizing the Future Communication Infrastructure (FCI) is consideration of technical solutions from the business perspective.

To address this topic, a business case analysis provided a high level estimate of the economic feasibility of an L-band aeronautical radio system from the perspective of a ground infrastructure provider. This initial analysis included the definition of a notional L-band ground radio system architecture that could meet the needs of the FCI as defined in the COCR. This effort included development of cost elements and estimates for development, operation and maintenance of the L-band system and then assessment of the required revenue flow to close the business case. By applying a number of assumptions (e.g. for the number of ground stations in a large area deployment; radio site configurations; element costs, etc); considering life cycle costs; and applying a standardized cost assessment methodology (Present Worth Simple Payback Method), it was found that a positive business case could be achieved within 4 years. While this high level cost estimate yielded positive results, an important feature of the study was the development of a suitable structured process for the analysis, which can be considered a framework for specifying infrastructure costs associated with an L-band system. Additional work is needed to assess the business case from the perspective of airlines. Additional details of this investigation can be found in the NASA Technology Investigation Phase II Final Report.

In addition, a business case assessment of an ATM satellite system was also carried out under the ESA SATCOM study. There were three funding scenarios considered: Private Finance Initiative (PFI), Private Venture (PV) and Public Procurement (PP). The PFI offered the best funding arrangements and is considered the most financially attractive to both public authorities and private investors. Some of its advantages are being more robust to cost and revenues uncertainties and gives best guarantees in terms of viability and permanency over years. A PV scenario did not look financially viable. Finally PP could be considered in the absence of private investors as it reduces the initial market take up risk. The key drivers identified in the study are the financial viability including Operator exposure to various risks, user equipment ramp-up, system size vs. service, and competition from other systems. Additional details of this work can be found in the ESA SATCOM study Final Report.

A business analysis is a key input to a decision taking process and needs to clearly address the expected benefits of the implemented operating concepts for all stakeholders. Therefore it is recommended to:

- Complete business analysis in relation to the FCI components and implementation from the perspective of the ground infrastructure and the airlines.

## Conclusions, Key Recommendations and Actions

The FAA/EUROCONTROL Action Plan 17 (AP17) has been a highly collaborative study with careful work planning leading to effective use of resources to avoid duplication, and successful information sharing. Among the major achievements of AP17, are the following:

- Establishment of future aeronautical communications concepts of operation and requirements;
- Identification of enabling technologies;
- development of a roadmap for the future communications infrastructure (FCI) that covers the transitions from now through to 2030; and
- Development of guidance and recommendations for the future aeronautical communications infrastructure.

The AP17 outcome is directly supporting the communication objectives of SESAR and NextGen. These are the two major programmes in Europe and the U.S. which are pacing the transition to the future ATM system. The AP17 outcome identifies the communication enablers to support the future operating concepts.

The very close and efficient cooperation between U.S. and European experts has enabled convergence and agreement on joint recommendations as directed by the ICAO 11th Air Navigation Conference (AN-Conf/11). The AP17 activities have been very closely coordinated with the participants of the ICAO Aeronautical Communications Panel (ACP) as a means to pave the way for the world wide consensus and global harmonisation.

The outcome of the AP17 activities identify that the FCI will be a system of systems infrastructure, integrating existing and new technological components aiming to secure seamless continuation of operations by safeguarding investments, facilitating required transitions and supporting the future requirements.

In summary, the key recommendations out of AP17 for new data link developments are the following:

- [R1] Develop a new system based on the IEEE 802.16e standard operating in the C-band and supporting the airport surface environment
- [R2] Complete investigations (with emphasis in proving the spectrum compatibility with other systems) to finalise the selection of a data link operating in L-band (L-DACS) and supporting

the continental airspace environment, aiming at a final decision by 2009, to enable system availability for operational use by 2020

- [R3]: Recognising that satellite communications remain the prime candidate to support oceanic and remote environments and that the considered future satellite systems may also be able to support continental environments possibly complementing terrestrial systems, monitor and support developments that will lead to globally available ATS satellite communications

Other key recommendations out of AP17 are:

- [R4]: Recognising the importance of spectrum for the realisation of FCI, ensure the availability of the required spectrum in the appropriate bands.
- [R5]: Promote/support activities that will enable/facilitate the airborne integration of the selected technologies.
- [R6]: Incorporate in any new data link system, provisions for supporting high QoS requirements in an end to end perspective.

Finally, it is recommended to:

- [R7]: Continue the close cooperation between the interested stakeholders and in particular between the FAA and EUROCONTROL in the realisation of the above recommendations.

The future joint FAA/EUROCONTROL activities should continue to be in the framework of the development of the required communication enablers for the NextGen and SESAR initiatives, which are leading the overall modernisation of the ATM systems in U.S. and Europe. In both regions, there is already active engagement of the key stakeholders (industry, airspace users, ANSPs, military. etc) in the NextGen and SESAR initiatives. However, the joint FAA/EUROCONTROL activities with a continuing close coordination of these activities in the frame of ICAO/ACP will reinforce and facilitate the global harmonisation.

The AP17 activities have identified a number of actions that need to be undertaken to secure the timely availability of the FCI meeting the considered requirements. Considering the long cycles in aviation to specify, validate, deploy and reach full system capability for any new system, it is critical that these activities are carried out expeditiously. The identified target date for an FCI initial deployment is 2020 and meeting this date needs continuous efforts to achieve the various milestones (validation, standardisation, commercial equipment availability, implementation decision, preoperational deployment and operations). Figure 4, as an example, depicts the key activities and the considered timings for the expedited development and deployment of the L-band component of the FCI targeting availability in 2020.

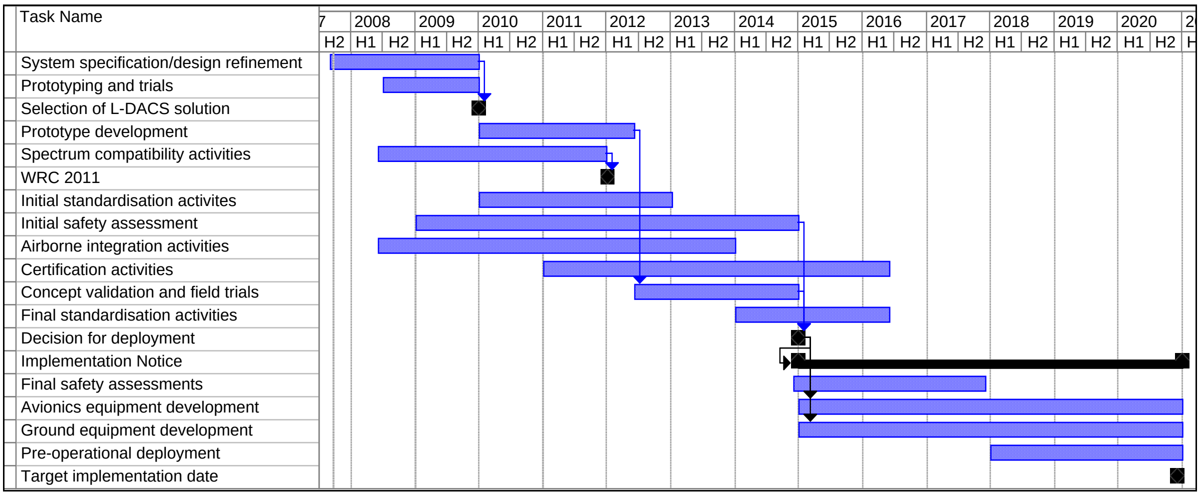


**Figure 4 – Target Plan for Expedited L-DACS Development and Deployment**

Based on the results of the AP17 activities a number of detailed actions emerge that need to be progressed in order to realise the key recommendations described above. There are different type of actions addressed to FAA and EUROCONTROL involving the ANSPs and the airspace users, to standardisation groups and organisations including ICAO, and Industry. The most important of these actions are presented in the next section.

## *AP17 - Resulting Actions*

The most important of the actions needed to realize the key recommendations are presented in the following paragraphs grouped according to the type of the required activity or the entity that will need to carry them out.

## *FAA and EUROCONTROL involving ANSPs and Airlines (in conjunction with the SESAR and NextGEN related activities)*

**General/Miscellaneous (Actions A0.X)**

- [A0.1] (supporting recommendation R7) Continue close cooperation in carrying out the following actions and relevant activities;
- [A0.2] (supporting recommendation R5) Support activities and engage with aircraft manufacturers, aircraft operators and industry standard groups to ensure that a flexible airborne architecture evolves to ease the cost and time of certification and readily accommodate new applications and technologies;
- [A0.3] (supporting recommendation R5) Encourage industry investigations into flexible airborne architectures, software defined avionics, and multi-function, multi-mode antennas; and
- [A0.4] (supporting recommendation R1, R2 and R3) Complete business analysis in relation to the FCI components and implementation from the perspective of the ground infrastructure and the airlines.
- [A0.5] {supporting recommendation R6) In order to finalise the selection of the new components of the FCI, carry out testing and validation within an end-to-end environment to ensure that the required QoS and performance can be achieved.

**C-band data link (Actions 1.X supporting recommendation R1)**

- [A1.1] Identify the portions of the IEEE standard best suited for airport surface wireless communications, identify and develop any missing functionality and propose an aviation specific standard to appropriate standardisation bodies;
- [A1.2] Evaluate and validate the performance of the aviation specific standard to support wireless mobile communications networks operating in the relevant airport surface environments through trials and test bed development;
- [A1.3] Propose a channelisation methodology for allocation of safety and regularity of flight services in the band to accommodate a range of airport classes, configurations and operational requirements.

**L-band data link (Actions 2.X supporting recommendation R2)**

- [A2.1] Refine and agree on the interference environment and assumptions for the L-band compatibility investigations;
- [A2.2] Develop L-DACS prototypes for testing and trials to facilitate the technology investigations for the selection of the L-band data link;
- [A2.3] Complete the investigation of compatibility of candidate L-band data link with existing systems in the L-band particularly with regard to the onboard co-site interference and agree on the overall design characteristics;
- [A2.4] Complete evaluation of performance of candidate L- band data link against the appropriate requirements in the various environments; and
- [A2.5] Considering the design trade-offs, propose the appropriate L-DACS solution for input to a global aeronautical standardisation activity; and
- [A2.6] Evaluate and validate the performance of the proposed solution in the relevant environments through trials and test bed development.

**Satellite data link (Actions 3.X supporting recommendation R3)**

- [A3.1] Continue monitoring the satellite system developments and assessment of specific technical solutions to be offered in the timeframe defined in the COCR as these next generation satellite systems become better defined;
- [A3.2] Update existing AMS(R)S SARPs performance requirements to meet future requirements; and
- [A3.3] In order to support the new AMS(R)S SARPs, consider the development of a globally applicable air interface standard for satellite communication systems supporting safety related communications.

**Spectrum (Actions 4.X supporting recommendation R4)**

- [A4.1] Continue to provide rationale to spectrum regulators on the need for additional AM(R)S spectrum to facilitate advances in aeronautical communication capabilities;
- [A4.2] Provide support for compatibility studies between the FCI and other incumbent systems in any newly-allocated AM(R)S bands. This will include studies within ICAO regarding FCI

compatibility with other aeronautical systems, and studies within the ITU regarding FCI compatibility with non-aeronautical systems; and

- [A4.3] Continue to support the need for priority to AMS(R)S in the satellite L-band.
- [A4.4] In the longer term, reconsider the potential use of the VHF-band for new technologies when sufficient spectrum becomes available to support all or part of the requirements.

### *Standardisation and Certification groups (including ICAO, RTCA, EUROCAE) (Actions B1.X supporting recommendations R1, R2, R3 and R5)*

- [B1.1] Initiate development of appropriate aviation specifications covering the 802.16e based system operating in the C-band;
- [B1.2] Await the outcome of actions 3.X to initiate development of appropriate aviation specifications covering the selected L-band data link;
- [B1.3] Update existing AMS(R)S SARPs performance requirements to meet future requirements;
- [B1.4] Consider the development of a globally applicable air interface standard for satellite communication systems supporting safety related communications; and
- [B1.5] Consider the optimisation of certification procedures and/or development of an integrated SW development environment in order to decrease certification cost for future components (particularly SDR)

### *Industry (Actions C1.X supporting recommendation R5)*

- [C1.1] Investigate the feasibility of a flexible airborne architecture and enablers such as software defined avionics, and multi-function, multi-mode antennas; and
- [C1.2] Support activities to ensure that a flexible airborne architecture evolves to ease the cost and time of certification and readily accommodate new applications and technologies.

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